# Normative Reference values of sideways walking, tandem walking, cross-stepping, heel walking and toe walking among children

SYNOPSIS SUBMITTED

To

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**Doctor of Philosophy**

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# Certificate

This is to certify that the PhD thesis synopsis / protocol on, **"NORMATIVE REFERENCE VALUES OF SIDEWAYS WALKING, TANDEM WALKING, CROSS-STEPPING, HEEL WALKING AND TOE WALKING AMONG CHILDREN"** has been done by NIDHI SHARMA under my supervision. I am satisfied with the work presented by the candidate towards the partial fulfillment of Doctor of Philosophy (PhD) in Physiotherapy. This is an original work submitted only to Maharishi Markandeshwar (Deemed to be University), Mullana-Ambala, Haryana, and is free of any plagiarism at the time of her submission.

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# Chapter 1: Introduction

## 1.1 Outcome measures and its significance

Outcome measures or assessment tools are required in every clinical and research settings to find any deviation from what is considered as the typical or normal for the respective variable.[1] For a clinician, the evaluation and assessment of a variable is very essential so as to enhance the knowledge of the normal and the impaired activities which further assist in keeping a check on the clinical attitude of the individuals along with the formulation of interventions accordingly.[2] In order to discover structural and functional limitations, methods of examination and assessment are essential, so as to develop the plan of treatment and also establish the effects of treatment.[3]

The assessment scales or instruments used for the clinical and research purposes should be selected on the basis of their psychometric properties and usability of that instrument for the required population, the selection of which can prove to be strenuous for the clinician or the researcher. The tools must possess the ability to evaluate the changes what they supposed to detect as inability to do so will lead to flaws in clinical decision and thus the rehabilitation of the patient can be affected. It may also compromise the internal validity of the study. .[2]

In order to avoid these flaws and errors, the assessment tools or the outcome measures must have the ability to have consistent results, measure it which they aimed to test and ascertain the changes when they endure in reality. These abilities make the outcome measure a reliable, valid and sensitive tool. Other properties which make the outcome measures more readily to use is the utilization in the clinical settings, must possess the reference norms, the cost and time of application with its difficulty level during application, the scoring and interpretation of the

results obtained after application. Hence, an assessment tool or the outcome measure should be easy to understand, administration and scoring can be done comfortably along with normative reference values so that the measures will have all clinical and research utilities properties.[4,5]

### 1.2 Significance of Normative Reference values

Reference norms are the observational, statistical or empirical values which provides with information about what is typical and usual for a given population or organization or in the health care system at a given time period and specify the particular characteristics of that group. The normative data thus obtained is helpful in making comparison of the testing group or individual with that of the reference group or individual. Hence, any variations can be noticed in the measuring group when compared with the characteristics of the reference population so that the extent of deviations from the benchmark can also be visualized.[6]

In the healthcare system, these norms are the important source of information so as to evaluate the influence of the disorder or any disease. These values also determine the effect of treatment interventions and able to distinguish between a healthy and unhealthy individual. The normative data is also helpful in the process of decision making by interpreting the results obtained.[6] Thus, it also reduces the prediction of being 'normal' by having the quantitative data to compare between 'normal' and 'abnormal'. As a whole it can be stated that normative values improves the reliability , and responsiveness of the outcome measures.[7]

### 1.3 Prevalence of Balance and Coordination disorders

There are various instances associated with coordination and balance deficits which make movement performance difficult such as developmental coordination disorder (DCD), cerebellar lesions, attention deficit hyperactive disorder etc. The prevalence of coordination disorders

among children greatly varies according to the conditions like it is 1.8% to 8% in DCD as per the diagnostic criteria with males are more affected than females,[8] 0.03% suffer from ataxia due to various disorders,[9] whereas the prevalence of Attention Deficit Hyperactive Disorder (ADHD) is found to be higher (8% to 15%).[10] The prevalence of loss of equilibrium and incoordination among adults was found to be 10% with age > 65 years and 25-50% in adults aged > 85 years.[11]

### 1.4 Falls and Disability adjusted Life years

Falls among children are very common due to a variety of reasons that may be categorized under fall from height, walker falls, poor socio-economic conditions, playground activities[12] or falls may be associated with any musculoskeletal or neurological affection within the body in age related disorders.[13] According to World Health organization, approximate 45000 deaths have been reported due to falls, out of which South-East Asian and low-middle income countries have the highest rate of fatal falls which accounts for 3.0% among boys and 2.4% girls per 100000 of population under the age of 20 years. It has been estimated that disability-adjusted life years (DALYs) is the resultant of fatal falls and non-fatal falls. Among all countries, south-east Asian countries have the maximum deaths due to falls with boys more affected than girls.[14] Disability adjusted life years is considered as a measure burden of unhealthy life.[12] Total DALYs after falls among children accounts for approximately 40%. Fall will occur if one cannot maintain the balance within the base of support or there will be a mechanical factor like poor postural control and a neural factor like impaired integration between sensory and motor functions.[15]

According to International Classification of Functioning, Disability and Health (ICF), health and disability has been divided into three categories: body functioning, activity and

participation. Any deficits in coordination and equilibrium may result in activity limitation and restrictions in participation that have influenced a person life to a great extent.[1]

### 1.5 Coordination tests

Coordination tests have been categorized into non-equilibrium tests and equilibrium or balance tests. Non- equilibrium tests used to examine the movement capabilities through limb coordination while equilibrium or balance tests maintain the static and dynamic balance of the body during perturbations.[16] For the subject's assessment, the level of challenges must be increased in these tests which customarily follow some pattern like first of all; activities are to be tested on one side, then to both sides but in proportional and congruous manner. Then it progresses to skew-whiff pattern in both extremities and lastly all four limbs could be involved. Challenges could also be imposed through perturbations or movement transitions.[17]

There are approximately 16 non-equilibrium tests, also known as tests for limb coordination/movements e.g. Finger to Nose test, Finger to finger test, Pronation-supination test, Rebound phenomena, tapping on hand and foot, past pointing test, heel to shin test and so on. Similarly 25 equilibrium tests are there which are also called as balance tests or the tests for postural control such as Sitting in a comfortable position, moving in all directions, standing on single leg, walk on toes, walk on heels, backward and sideways walking, cross-stepping, tandem walking, Romberg's test, sharpened Romberg's test etc. Although these are just an approximate figure and are not all-inclusive. Various methods can be utilized to check the coordination in different functional skills like activities of daily living, during transition of movement or position of limb/body, during transfer from bed to wheelchair and vice-versa etc. It should be noted that equilibrium tests followed the non-equilibrium tests.[17]

### 1.6 Assessment tools/Outcome measures for coordination

There are specialized tools which can quantify these tests like *CATSYS* System and Choice Reaction time Analyzer. Some tools are used to quantify upper limb coordination like Purdue Pegboard Test, Jebsen Taylor Hand Function test, Minnesota Manual Dexterity test, O'Conner Tweezer Test and Finger Dexterity test etc. Some instruments quantify the balance tests such as Berg Balance Scale, Functional Reach Test, Multidirectional Reach Test, Timed up and Go test, Performance Oriented Mobility Assessment, Timed tests, sitting balance tests, Dynamic Gait Index and so on. Many of these instruments and tools are reliable and valid measures to use and they have their reference values to compare the normal coordination/balance/postural control with that of the abnormal one.[17] But these measures lack the use of basic field tests which have been mentioned under equilibrium and non-equilibrium tests.

### 1.7 Goals of examination

Coordination assessment and examination has been done so as to evaluate the muscles ability to work synchronically to accomplish any functional task, to initiate a movement and then to control and terminate it. The other goals are arrangement, accuracy of movement's pattern and its timing. Also the peculiarity of muscle activity during voluntary movement along with paraphernalia of pharmacological and therapeutic treatment on motor function over time and the efficiency of movement and skills level are also some of the goals of coordination examination.[1]

There are various coordination tests which can assess the ability of an individual to perform an activity or to maintain the posture while performing an activity. Hence, quantification of coordination is of utmost importance for clinicians to academicians as it can enlightens the

pathway of the therapeutic interventions as well as provide guidance to provide a thorough assessment of the cardinal and substantive neuromuscular deficits in a potentiate individual.[1] The evaluation and assessment of motor coordination is very essential so as to enhance the knowledge of the normal and the impaired motor activities which further assist in keeping a check on the clinical attitude of the individuals along with the standardization of the treatment protocol.[2]

**1.8 Available reference values for outcome measures**

The reference values of some of the balance and coordination tests have been established like timed balanced tests, Single limb stance test and Tandem stance for different age groups. These values help to avoid predictability of normal from that of abnormal ones among clinicians or researchers especially when the individual has been assessed after an injury or during the study period of a research respectively.[18,19] There exist other assessment tools also which assess the coordination or balance like some of the non-equilibrium coordination tests e.g. Supination-pronation test, heel to shin test, finger to nose test, mass grasp, opposition grasp etc. but their reference values are available in adults only.[20] Reference values for another balance tool, Clinical test for Sensory Integration and Balance are available in children in the age group of 9-10 years. Other measures like Six Minute Walk Test (6MWT), Time up and Go test (TUGT), Berg Balance Scale (BBS), Gait Speed, Multi Directional Reach Test (MDRT), Sharpened Romberg Test (SRT), Physical Performance Test (PPT) having normative data in the age group more than 50 years.[21,22]Another assessment tool i.e. Lower Extremity Motor Coordination test has the normative values for more than 20 years of age. Such instances show that there is scarcity of literature for the normative reference values of the non-equilibrium coordination tests among children involving walking activities.

As stated earlier, there are more or less 25 equilibrium coordination tests and out of those, few of them have the reference norms such as single leg standing,[23],[19] tandem stance,[19] multi directional reach tests,[22] Sharpened Romberg's test.[22] But none of these tests involve equilibrium in walking to the best of my knowledge. Thus, the present study aimed to report the normative reference values of five equilibrium coordination tests which involve walking among age group 8-15 years so that these values can be used by clinicians and researchers or the rehabilitation professionals to differentiate between normal and abnormal coordination.

### 1.9 Need of the Study

To the best of my knowledge, the normative reference values of equilibrium coordination tests specifically sideways walking, tandem walking, cross-stepping, heel walking and toe walking, are not available among children of age group 8-15 years. Therefore, it is a definite need to establish these values among children that involves walking abilities so that they can be used for all clinical and research purposes.

### 1.10 Research Question

What are the normative reference values of sideways walking, tandem walking, Cross-stepping, heel walking and toe walking among children?

### 1.11 Aim of the study

To establish the normative reference values of sideways walking, tandem walking, cross-stepping, heel walking, toe walking among children.

### 1.12 Objectives of the study

To find the normative reference values of sideways walking, tandem walking, cross-stepping, heel walking, toe walking among children of 8-17 years of age

## Chapter 2: Review of Literature

### 2.1 Balance and Coordination

Balance can be defined as the ability to maintain the body mass in relation to the base of support in typical all daily routine work among adults and school activities and outdoor playing along with activities of daily living in children. Hence two categories of balance have been described as Static and Dynamic balance where body position plays a vital role in maintaining balance and coordination for keeping a stable posture during transition of body position from one position to other or during any kind of movement execution. Base of support, position of the center of gravity (COG) and Line of gravity (LOG) are the key components which are related to balance. Balance is one of the most basic motor abilities, of which the development starts in the childhood.[24]

Coordination is the harmonious movement of the body segments executed by different muscles or muscle groups in order to fulfill required environmental demands. Coordination develops via three main aspects: (1) quality of training (2) versatility (3) variety of situations in which the subject is placed. For the development of the coordination components, the individual's perceptual capabilities should be improved and well trained.[25]

### 2.2 Physiology and Biomechanics of Coordination

To produce a coordinated movement, the involved neuromuscular system should come into action at the well-judged time with the required amount of muscular force.[17] It is one of the components of the motor control which regularize the mechanism that is required to produce a movement.[25] The muscle tension is selectively distributed across respective joints through the postural adjustments and thereby movements to serve the purpose for the same. This whole task has been controlled by central nervous system and is defined as the motor control theory. Hence, mechanism of postural adjustments, control of muscle tone, coordination and allocated movements are the constituents of motor control.[24]

This neuromuscular control plays a vital role in materialistic concepts of coordination for inter-segmental coordination, intra-limb coordination or inter-limb coordination.[1] There could be visual-motor coordination and eye-hand coordination too. Intra-limb coordination indicates the movements which occur within a single limb (e.g. motion of a unilateral lower extremity during a gait cycle or the use of hand to comb the hair). The coordination between two or more limbs depicts Inter-limb coordination (e.g. coordination between lower limbs during gait cycle or during any activities of daily living like dressing for upper limbs coordination). When these motor skills are combined with vision so as to perform a task and thus an aim can be achieved, this comes under the category of visual motor coordination (e.g. vehicle drive, cycling, writing, or a zigzag line is traced). A subcategory of visual motor coordination is eye–hand coordination required for using personal hygiene, eating utensils or reaching for a target (e.g. to change a bulb from the socket). Basically it would be better to called coordination between eye, hand and head as head follows the movement of the eyes so as to target an object.[17 26]

A human body could have multiple degrees of freedom in joints and muscles, more than the required number to produce a movement but it is the integrated activity of cerebral cortex,

cerebellum, brain stem and spinal cord to produce a coordinated activity in the desired form by triggering the motor commands for that movement.[27,28] Multiple effectors like muscles, joints and limbs work simultaneously to follow the motor commands imposed on body and environment so as to fulfill the desired outcome.[25]

Effective balance requires intact coordination movement. There are several brain areas including which are responsible for coordination between hand and foot movement or inter limbs coordination[29] like supplementary motor area, cingulate motor area, premotor cortex, primary sensor motor cortex, basal ganglia and cerebellum.

The neuro-muscular system can be categorized into central elements and peripheral elements where the peripheral somatic system involves joints, muscles, or their motor and sensory innervations, the central elements can be further classified into three hierarchical levels to help in understanding their delineating and contribution of neuroanatomical structure. The highest level is incorporated with basal ganglia and neo-cortex which follows the movement strategy and purpose of the movement. The middle level is constituted by cerebellum and the motor cortex where the sequences of muscle contractions are arranged according to time and space which are then recommended for accurate and smooth attainment of the strategic goals. Spinal cord and brain stem constitute the lower level in hierarchy which are related with the execution of movement performance through interneuron pools and motor neuron activation that engender the goal- directed movement or make adjustments for any type of posture. According to Flexible hierarchical theory, each level of nervous system can affect a level above and below of itself depending upon the demand of the task.[30]

The motor system acts as a parallel arrangement. There are many crucial brain areas helps in motor function such as the motor cortex, which includes Brodmann's (cortical areas 4 and 6) located in the precentral gyrus, also known as demarcated area of the frontal lobe. Neurons in human body are correlated and form structural and functional networks. The human brain's complex processing capabilities are responsible for temporary coordinated communication within and between these networks (precentral gyrus and Brodmann's areas). The communication and movements are denoted by a dynamically functional interaction in the cerebellum-thalamo-cortical network with organize brain oscillations in the alpha and beta ranges, bimanual coordination such as complex movements, oscillatory activity between and within the right and left hemispheric motor networks. However, planning coordinated movement to perform a specific task involves areas of neocortex which is required for the location of target, position of body in space, select the movements i.e., joints, body segments and muscles will be involved, storage of memory until execution of time and specific instructions to impose the selected movement strategy.[31]

The essential role of sensory input on motor system cannot be overlooked. An internal representation of the environment that guides and inform the motor responses provided via the sensory input integration. The coordinated, planned, implemented and purposeful movements are provided via the foundations of the motor programmed and sensory input integrations. The sensory input to the motor system governs adaptation and selection of motor responses or motor programs shapes for corrective actions. For examples, the somatosensory system give the important information for walking while moving from the smooth terrain to the uneven surface; for maintenance of standing balance in a moving bus; or to make the mandatory adjustments while throwing a ball from a chair (stable sitting surface) versus therapy ball (unstable surface).

The contributing factors of sensory impairment are coordination impairments, sensory examination precedes coordination examinations.[30–32]

Coordinated movement includes the right amount of force generated at the correct time so that the muscles can be actively participated in the performance of the movement. Arrangement and then classification of muscles activation are the necessities of a coordinated movement. As stated all systems like somatosensory, vestibular, visual and neuromuscular system are required to activate these responses. Coordinated movements are exhibited through appropriate distance, speed, time, direction and muscular tension. All the basic principles of group action of muscles are applied in order to execute a movement at the distal segment[17]

**2.3 Coordination and its types**

Coordination includes two components – dexterity and agility where dexterity refers to fine motor movements while agility means to swiftness in the body to adapt environmental demands with postural control.[28] Three systems are basically involved in the mechanism of postural control i.e. peripheral system through visual, vestibular and somatosensory feedback; central system through cognitive feedback; and the musculoskeletal system.[11] As it is a function of multiple system involvement, therefore neuromuscular coordination steps it's footprint in the pre-school children and persistent throughout life. It can be exhibited in everyone's day to day life, starting with basic activities of daily living (BADL) to instrumental activities of daily living (IADL).[33] From grooming oneself to going market for shopping requires dexterity and agility in upper extremities as well as in lower extremities which ranges from inter-segmental to inter-limb coordination.[1,2]

**2.4 Coordination and its control**

Coordination can be achieved when different effectors work concomitantly which results in hierarchical coordination among intra-limb coordination (between different muscles), inter-limb coordination (between joints) and inter-limb coordination (between limbs). Movements are done and effectors work so as to control the relevant state of the body for the required task and its environment. An optimization process is required for the accomplishment of a task that is required to fulfill by the individual and thus it is the task structure and body of the individual which determine the coordination and not the internal constraints imposed by the nervous system which can be understood by the Optimal Feedback Control theory by focusing the importance of sensory feedback during movement. The effectors are dependent on each other directly where effectors are coupled biomechanically or indirectly where the effectors are not mechanically linked but they are related through common task variable on which they are required to act through motor commands resulting in coordination. This highlights the role of state estimates at central and higher level where the motor control and coordination can be achieved through flexibility in cognition rather than hard-wired and rigid coordination constraints during bimanual coordination.[25]

The goal for the completion of task is to sustain the centroid of body over the base of support in order to control the balance which can be attained by different biomechanical principles like kinetics, kinematics etc. There is a hierarchical organization of the nervous system where the temporal pattern of activity of muscles is followed by spatial pattern and these are controlled by the regulation of task-level objectives so that the movement can be executed. This translation of temporal control into spatial pattern has been governed by muscle synergies which demonstrate that there is activation of many muscles to produce a harmonious and congruous biomechanically sound movement. Hence a coordinated task has been accomplished by lending

insights of the biomechanical principles and the neural constraints in healthy and unhealthy individuals.[34]

As it has been discussed that human movement is the result of coordination between nervous system, musculoskeletal system and the relative environment, it is also necessary to understand the dynamic characteristics of this neuromuscular mechanism and the mechanical interactions with the environment where the movement has to produce. For this purpose, muscle synergy is the key factor to analyze the concepts of adaptive locomotion and its different phases where sensory-motor coordination is required. During transition to stance phase from the swing phase, it has been observed that the required muscle force is completely dependent on the dynamic role of the foot i.e. either the foot is in the air or in contact with the ground. Motor commands also follow the patterns of the foot contact means motor commands must be early or delayed if there is early contact of foot or delayed contact to the ground. While in the opposite phase of stance to swing, force-sensitive sensory information to reduce the ankle extension and position-sensitive sensory information for sufficient hip extension commands the motor control during this transition. Inter-limb coordination is also required during loading and unloading the limb specifically in case of avoidance of any obstacles during walking. When the front foot is lifted higher than normal to overcome the obstacle, there is delayed foot contact and when it is prolonged the trailing foot loses its support which require additional inter-limb coordination to avoid the obstacle and get the success. Therefore, it can be concluded that the muscle synergies are the indicators which analyze the neural mechanism for the representation of body in the brain.[27]

## 2.5 Coordination and Cognition

Motor skills comprises of gross and fine motor skills which may include jumping, locomotion and other physical capabilities like strength, flexibility or balance and fine motor precision respectively. These skills also include bilateral motor coordination and timed performance in movements where timing and sequencing in the performance of movement is important for consideration. Cognition is the process of obtaining and getting information with comprehension through thoughts, familiarization, knowledge and the senses. These cognitive skills may include higher level cognition i.e. executive functioning, planning, suppression of responses, attention and concentration, long term and short term memories, visual processing and fluid intelligence along with crystallized intelligence, intelligence quotient and academic skills.[33]

Motor skills and cognition are co-related among children as there is simultaneous activation of prefrontal cerebral cortex, basal ganglia and the cerebellum during various new or complicated tasks or when the conditions for performing an activity changed, an instant action and concentration are required so as to perform an activity/task. Then the development of motor and cognitive skills occurs concurrently and their developments hasten between the age of 5 and 10 years. Also these two include similar elementary processing which are sequencing, observing and planning. There exists a strong relationship between fine motor skills, bilateral body coordination and timed coordination with cognition in comparison to balance and strength as there is greater cognitive imposition is associated with complex motor skills. There is a weak evidence that the bilateral body coordination and timed performance are strongly associated with fluid intelligence which is required for performing complex motor tasks while fine motor skills is associated with academic performance and skills in pre-pubertal age. Conversely these variables showed strong evidence for their strong relationship for the age after 13 years of age. These

findings support that motor skills and cognition equally develop in young children and it get accelerated for children of 5-10 years of age.[33]

There are children who face difficulties in the development of their motor skills during their development phase which may be associated with psychological or behavioral problems and cognitive skills is one of them which are difficult to coordinate in a particular environment. Neural behavior of cognition has been related to motor skills and learning during locomotion, postural control, fine motor activities of hands, movements of eyes and praxis. All these tasks or activities are required to perform in a particular environment as per the nature of the task. Children with developmental coordination disorder not only suffer from motor deficits but their cognitive skills are also involved which contribute in rhythmic incoordination and perceptual-motor deficits. Mirror Neuron System and internal modeling are the theories through which knowledge of relationship between motor skills and cognition can be gained where observation and action performance or the effector systems working between gross motor movements to fine motor movements are explained. Children with DCD exhibit performance deficits in these effector systems, resulting in requirement of prolonged practice to learn a task and in converting that task into a complex skill. Deficits in observation-action performance are also evident along with impaired executive functions.[35]

**2.6 Significance of field tests**

The field tests are predominantly used for physical fitness which include various components like cardiorespiratory fitness, muscular fitness, anthropometric measurements like body mass index and waist circumference, motor skills such as speed and agility and neurological fitness that include balance and coordination. These biomarkers are consistently

related to the health indicators like musculoskeletal health, mental health, obesity and cardiovascular health.[36] The cardiopulmonary fitness is in reciprocal proportion with the risk of cardiovascular health risk during childhood which is also an indicator of poor physical fitness.[37] Among all health indicators, motor skills of a person are dependent on balance and coordination which are in turn useful for determining the dexterity and agility of an individual.[28] Hence, assessment of physical fitness is essential to evaluate the effect of any genetic or environmental factors on these biomarkers and the tools of assessment of physical fitness are low-cost and application of these tools are safe and simple. Although these tools should be valid and reliable and feasible to use in every set-up[36] along with their established reference norms so that there can be clear distinguish between a nornal fitness and an abnormal fitness.

## 2.7 Normative Reference values (NRV)

Normative data is different for different populations, for different cultures, and can be changed over a period of time. The values help to interpret the results in various areas like health related area, psychology or other fields like well-being. In the history of medical science, growth assessment of the infants was assessed by the normative values of height and weight of the children. These values were also used to determine the cardio-pulmonary status, biomarkers and the neurological conditions of the respective patients. Few of the Intelligence tests have the reference values which are being used in the field of psychology for more than a centuary.. Norms of Health related Quality of life questionnaires were being used as a part of the assessment of the individual's well-being. Hence, it can be stated that these normative data are continuously used to find any changes in the measures used in different populations or cultures.[6]

### 2.7.1 NRV for Single limb stance

A prospective mixed-model study was conducted on 549 healthy subjects with age more than 18 years to estimate the NRV of single limb stance. All the participants were categorized into 6 categories based on the age groups as 18-39, 40-49, 50-59, 60-69, 70-79, >80 years. Subjects were asked to stand on dominant limb with eyes open and with eyes closed. The mean of three readings have been identified for the reference values. Mixed-model ANOVA has been used to find the factor interaction which showed that group and test interaction was significant with F value = 35.52, p = 0.001. Reference values have been identified for different age groups and for females and males separately. For the age group18-39 years, the values were identified as 43.3 (5.1) seconds with eyes open and 9.4 (9.4) seconds with eyes closed. For the age group 40-49 years, the values were 40.3 (10.8) seconds with eyes open and 7.3 (7.0) seconds with eyes closed. For the age group 50-59 years, the values with eyes open were 37.0 (12.6) seconds and with eyes closed, 4.8 (4.8) seconds. For the age group 60-69 years, the values for eyes open were 26.9 (16.6) seconds and with eyes closed, the values were 2.8 (2.2) seconds. For the age group 70-79, the reference values with eyes open were 15.0 (13.9) seconds and with eyes closed, the values were 2.0 (1.6) seconds. For more than 80 years, the values were 6.2 (9.3) seconds with eyes open and 1.3 (0.6) seconds with eyes closed.[23]

Another descriptive study also estimated the reference norms for unipedal in 250 children of age group 7-14 years. Tests were performed on both feet one by one. No significant correlation was found between Body Mass Index (BMI) and coordination but age was found to be significantly correlated with the balance tests. Mean value of unipedal were found to be 1.14 – 2.55 seconds. No significant difference was found between both sexes.[19]

### 2.7.2 NRV for Tandem stance

250 children of mean age 11.76±3.5 years were recruited to find the normative data of tandem stance. Subjects were instructed to keep their left foot in front of their right foot while touching the toes of rare foot with the heel of fore foot. Significant association was found between age and the test but no significant correlation was found between BMI. Mean value of tandem stance were found to be 1.47-3.26 seconds. No significant difference was found between both sexes.[19]

Normative values for Tandem stance were further discovered in adult women of age group between 60 and 80 years. Nearly 200 women were recruited to find the reference values of tandem stance to test the static balance. Stratified sampling was done according to the age group. Subjects placed their one foot in front of other by touching the heel of one foot with toes of other foot by taking the support of the assessor arm. When the subjects were feel stable, then the support was removed and the duration of standing was noted. The maximum time was 10 seconds hold. Median for both age groups was found to be 10 and mean (standard deviation) obtained were 9.49 (1.33) seconds and 8.89 (2.34) seconds in age group 60-69 and 70-79 years respectively.[38]

### 2.7.3 NRV for Sharpened Romberg's test, Multi Directional Reach Test, Berg Balance scale and Physical Performance test

Multidirectional Reach test (MDRT) and Sharpened Romberg's test (SRT) are equilibrium coordination tests while Berg Balance scale (BBS) and Physical performance test (PPT) are the balance tests. The reference values for these tests have been identified among 83 adults having age between 50 and 90 years. For MDRT, participants performed the test in forward, backward, right and left directions. While performing the test, they were asked to lean

in particular direction with one arm extended by making a fist along a yardstick. Feet should rest on the floor and they have to lean as much as possible without raising the feet or losing balance. The distance from the initial and final position of the fist has been noted in three trials after giving one practice session. Mean (standard deviation) and 95% confidence interval were assessed to find the reference values. The results showed that the values were same for right and left reach i.e. 17(5) meters, 16-18 meters respectively while for forward and backward reach; the mean values were 29(7) meters, 28-29 meters and 19(8) meters, 17-20 meters. The effect of age, height, weight on the test was also evaluated using multiple linear regression analysis which showed that height has the significant role in backward reach.[22]

For Sharpened Romberg's test, participants were made to stand in tandem stance position with dominant foot placed behind the non-dominant foot for 1 minute. The test was performed in 3 trials with eyes open and eyes closed. The best of 3 trials has been recorded as the reference norms. Results showed that 77% of the participants were able to maintain balance with eyes open while with eyes closed, only 30% maintained their balance. The mean (standard deviation), confidence interval obtained after testing were 49(21) seconds, 45-54 seconds with eyes open and 29(24) seconds, 24-35 seconds with eyes closed. Age, height and gender were significant factors in estimating the values with eyes open, while age and gender were found to be the contributing factors for testing Sharpened Romberg with eyes closed.[22]

Next the Berg Balance Scale was tested which constitutes 14 items to check the balance and fall risk among elderly. All the items were evaluated on 0-4 ordinal scale except item no. 8 which refers to forward reach which has been evaluated during MDRT. The best score is 56 for all the items. Results indicated that the subjects with age more than 80 years scored less than 45

which is considered as the baseline for the prediction of fall risk. All the factors i.e. age, gender and height have significant influence on the outcome and thus the fall risk of the individual.[22]

Berg Balance Scale was also evaluated among older adults of age between 60-89 years categorized into three groups on the basis of their age as 60-69 years, 70-79 years, and 80-89 years. 96 individuals have participated and performed the test as instructed. The result showed that scores of both sexes between the age group 60-69 were same i.e. 55 with a narrow confidence interval of 55-56 while there was a slight difference observed in the age group 70-79 with mean value of 54 and 55 for males and females respectively. The values for older age were 53 and 50 for males and females with confidence interval vary from 49-54.[21]

Upper extremity coordination, balance, mobility and endurance were tested through 9 items Physical Performance test (PPT-9) and also through 7-items PPT. This test consists of 9 items and 7 items respectively and measured on 5 point likert scale scoring from 0-4 where score 36 and 28 scores indicate best performance. Results of the study showed that 30 (3), 29-30 was the mean (standard deviation) and confidence interval for the PPT-9 whereas 22(2), 22-23 were the reference norms for PPT-7. Age is the only factor which produced significant effect on the performance of the test.[22]

### 2.7.4 NRV for Non-equilibrium Limb Coordination tests

Normative data was obtained from a cohort of 69 older adults with mean age of 66.2(2.7) years, 73.3 (2.0) years and 82.7 (2.8) years among the age group of 60-69 years, 70-79 years and 80-89 years. Five tests were performed named as Finger-to Nose test, Pronation-Supination test, Mass grasp. Finger-Opposition and Heel-on-Shin test after obtaining the demographic details of the subjects which included height, weight, gender and hand dominance. Five readings were

taken for each test. Participants were made to sit during testing except during heel-to-shin test, where the subjects were asked to lie supine. The reference values obtained for finger to nose test among age group 60-69 years was 3.6(1.0) seconds, 3.9 (1.0) seconds for 70-79 years, 4.6(1.1) seconds among age group more than 80 years. For pronation-supination, the value was 2.9(0.6) seconds, 3.1(0.6) seconds, 3.5(0.6) seconds among three age groups respectively. The data extracted for mass grasp was 2.4(0.8), 2.6(0.8), 3.0(0.8) seconds for all three age groups. 6.3(1.8), 7.2(1.9), 8.3(2.0) were the reference values for finger opposition for the age groups between 60 and >80 years. The values for finger opposition tests were 4.1(1.1) seconds for the age between 60-69 years, 4.3(1.1) for the age between 70 and 79 years, 4.6(1.1) seconds was the norms for the age > 80 years. It was also observed that weight, BMI and handedness did not contribute to the performance of the individuals although height was found to be negatively correlated with the timed performance of the subjects.[20]

### 2.7.5 NRV for Timed walk test

#### 2.7.5.1 Six Minute Walk Test (6MWT)

The clinical measures to test physical mobility and balance were used to find their normative values among older adults of age more than 60 years. 96 participants were volunteered for the study. Stratified sampling was done according to the age of the individuals i.e. 60-69, 70-79 and 80-89 years. 6MWT is a measure that is commonly used to assess the cardiopulmonary status of the individual. It is a modification of 12 minute walk test. The test was conducted using a 30x2.3 meters walkway of linoleum with marking of 1 meter progression up to 6 meters. The subjects were asked to walk as far as possible in 6 minutes with 2 assessors placed at either ends of walkway. Practice trial was performed, and then the participant was made to relax till his heart

rate returns to normal. The distance of the 2nd trail was noted to the nearest meter and used as data for analysis.[21]

Reference value of 6MWT has been evaluated in the children of Turkey with age group 6-12 years. 262 healthy children were recruited and their demographic characteristics have been measured such as age, gender, height, weight, BMI and limb length. Children were explained the procedure as per the guidelines of American Thoracic Society. The values thus obtained were expressed in mean and standard deviation having a mean value of 572.5 (117.7) meters among all age groups. It was found that children with smaller age group covered lesser distance as compared to larger age group varied from approximately 445 meters to 720 meters in 6 minutes.[39]

Another study found the normative value of 6MWT among 442 healthy boys of age group 5-12 years from Belgium. The testing procedure had been demonstrated to all children. It was found that the walking distance in 6 minutes was progressively increasing with age. The calculated value was 478 meters at the age of 5 years and 650 meters at the age of 12 years.[40]

Reference value of 6MWT was also identified among 102 young adults with age group 20-50 years and the results showed the mean value of 638 meters with standard deviation of 44 meters among males and 593 meters with standard deviation of 57 meters among females. [41]

444 healthy adults were recruited between the age of 40 and 80 years and the normative data was obtained among these ages. The mean and standard deviation thus obtained for all age group was 571 (90) meters where men covered larger distances than women with a lap of 30 meters. It has also been observed that age is the significant factor in determining the distance covered in 6 minutes where older adults took much time than that of adults with less age.[42]

It has been concluded that the reference range of 6MWT varied from 478 meters for 5 years old children, and then it increases in adulthood and reaches to a peak of 638 meters for persons of middle age group and approximately 570 meters among older age group. It has also been observed that no study clearly explains about the type of footwear used for walking or the individual needs to walk barefoot.

A systematic review was conducted on six minute walk test to evaluate the functional capacity after long term follow up treatment of critical illness along with the comparison of walking distance in 6 minutes in patients with Acute Respiratory Distress Syndrome (ARDS) and non-ARDS. 26 articles have been selected from 5 databases till February 2018. It was found that the pooled mean of six minute walk distance (6MWD) at 3 months was 361 meters with 321-401 meters as 95% confidence interval while this distance was hiked to 436 meters with 95% confidence interval of 391-481 meters. It was observed to be decreased at 60 months with a mean value of 411 meters. When the values of 6MWD was compared among ARDS and non-ARDS survivors, the result depicted that the mean of 6MWD was 73 meters lower in ARDS than that of patients with non-ARDS with the confidence interval of 13-133 meters. It has been concluded that the distance covered in 6 minutes was better at 12 months after critical illness but when comorbidities exist, its value was found to be lower.[43]

Another systematic review has been done to determine whether 6MWT assesses the functional capacity of children and adolescents suffered from cystic fibrosis.6 articles were include out of 695 articles from eight databases. The results interpreted that 6MWT is not correlated with lung function but it can be reproduced in patients with cystic fibrosis. Also it proves as not a valid tool for this population.[44]

#### 2.7.5.2 NRV for Two Minute Walk Test (2MWT)

2MWT is a modified test of 6MWT which was proposed by American Thoracic Society. The whole procedure is same as that of 6MWT except the required distance to be covered in 2 minutes rather than 6 minutes. The reference data for 2MWT among 1137 individuals with age more than 18 years up to the age of 85 years has been estimated. Adults have been categorized according to the age into 7 categories – 18-54 years, 55-59 years, 60-64 years, 65-69 years, 70-74 years, 75-79 years and 80-85 years. It was observed that the mean data obtained among age group 18-55 years was 191.95 meters, between age 55 and 59 years was 183.7 years. For age group 60-64 years, the mean value was 172.7 meters while it was 169.7 meters for the age group 65-69 years. Among adults of age 70-74 years, the value was 159.1 meters, for age group 75-79 years, the value obtained was 149.2 meters and finally the value was 139.2 meters for oldest group in the study. It was also observed that men covered larger distances than that of women.[45]

The normative reference values of 2MWT among children were also determined among age group 3-17 years using the same procedures as explained among adults. 2631 children were volunteered for the study after obtaining the consent from their parents. The mean value of overall distance covered by all ages was 186.2 meters with standard deviation of 33.9 meters.[46]

#### 2.7.5.3 Ten Meter Walk Test (10MWT)

A cross sectional study recruited 120 children with age group 6-12 years with the aim to find the intra-rater reliability and test-retest reliability of 10MWT. The examination of the test was done at 2 velocities i.e. self-controlled and fast velocity. Mean velocity developed at 10 meter and 6 meter was also compared and found its relation with acceleration and declaration phases of gait along with the anthropometric measurements. The child was asked to walk

barefooted on a gymnasium ground for 10 meters following a familiarization session. Child had to walk at self-controlled speed and fast speed to cover a distance of 6 meters and 10 meters. Two assessors evaluated the distance and time taken at 6 meters and 10 meters. For the calculation of 6 meters, the assessor had not considered the initial 2 meter distance and final 2 meters distance. Test-retest reliability was measured on $1^{st}$ day and on $7^{th}$ day, denoted by ICC (Intra class Correlation Coefficient). 3 readings have been obtained for each test. Multiple regression analysis was used to find the relation of anthropometric measurements and the mean velocities at 6 meters and 10 meters. The results showed that ICC values for intra-rater reliability during self-controlled velocity at 6 meters and 10 meters was found high (ICC = 0.70-0.89) for the ages of 6, 8, and 12 years children. When it was evaluated during fast speed, ICC was found to be moderate (ICC=0.50-0.69) at 6 meters for children of age group 6 and 12 years while at 10 meters, high reliability was observed for all ages (ICC=0.70-0.89). The mean velocity at self-controlled and fast velocities at 6 meters and 10 meters for test-retest reliability was found to be moderate to low (ICC ranges from 0.20-0.69) for all ages. It was also observed during regression analysis that height significantly affected the mean velocity when the children walked for 10 meters at self-controlled speed ($\beta$=0.997). Hence, it was concluded that intra-rater reliability was high for fast speed during 10 meters walk while test-retest reliability was found to be increasing during self-controlled and fast speed for 10 meters walk.[47]

Another study evaluated the clinical significance of ten meters walk test in patients with mild Parkinson's disease (PD). 151 patients with a mean age of 68 years were recruited for the study. Their gait velocity had been assessed during 10 meters walk when they asked to start with a static speed and then a dynamic speed with 2 readings each. The patients were walking at their comfortable speed and gait speed was measured using a digital stop watch. The results showed

that mean and standard deviation of gait speed at static start during first reading was 1.132 (0.290) meter per seconds while it was 1.112 (0.278) meters per seconds during dynamic start which showed a statistical significant difference ($p<0.001$) in all patients. Thus it was concluded that repeated trials and accelerated distance were not required to perform the 10MWT in patients with mild PD.[48]

It has observed that six minute walk test is a tool which aims to test the functional capacity of the individuals and thereby their endurance as they are required to walk for at least 6 minutes to cover a larger distance. In comparison to 6MWT, ten meter walk test is a valid and reliable tool which quickly measures the ambulatory status of the individuals by assessing the gait velocity. 10MWT proves to be an easily administered outcome measure, the results of which are readily interpretable in comparison to 6MWT.[49]

### 2.7.6 NRV for Time Up and Go Test (TUGT)

Time up and go Test (TUGT) is a measure which is used to measure dynamic balance among older adults and is a predictor of fall risk. The test was performed by asking the subject to stand from a chair with arm rest, walk for at least 3 meters, take a 180 degree turn, then walk up to the same chair and then turn 180 degrees and then sit down on the chair. The assessor will note down the time for the whole task. In the study, 192 elderly females of age group between 60 and 80 years were recruited. They were categorized into 2 groups based on the age limits as 60-69 and 70-79 years. After giving a practice trial, mean of next two trails was recorded. The results showed that the reference values for the age group 60-69 years are 5.3 seconds which was considered as ‘very good’ score while a score of 7.2 was considered ‘very poor’. Among the age

group 70-79 years, the reference values for very good score are 5.9 seconds and 9.1 seconds was considered as very poor score. Thus a qualitative and quantitative readings were obtained.[38]

Reference norms for TUGT were also evaluated among older adults between the age 60 and 90 years. 96 individuals have participated in the study. The procedure of the test was clearly explained to all the participants and a practice session was performed. Then the average of the next two trials was recorded and underwent analysis. It was observed that there was a difference of 1 second in the mean value in three different age groups i.e. from 60 to 69, 70 to 79, 80-89 years, ranges from 8 to 10 seconds which showed that as the age advances, more is the time required to complete the task.[21]

### 2.7.7 NRV for Functional Reach Test (FRT)

Functional Reach test (FRT) is a measure used to assess balance and it is performed by asking the subject to stand in close approximation to a wall perpendicularly with feet resting on the ground. One arm of the subject is stretched at 90 degree and the position of the 3$^{rd}$ metacarpal was marked. Then the subject was asked to reach forward as much as possible without losing balance and heel off the ground. The new position of the 3$^{rd}$ metacarpal was noted. The difference between the initial marking and final marking was measured in centimeters. In the study the reference values for elderly female between the age group of 60 and 80 was found to be 37.4 cm and 35.7 cm for the age group 60-69 and 70-79 years respectively. These values showed a very good balance among individuals.[38]

Normative Reference Values of FRT was also estimated among older adults from the new and old published data. From the new study, 199 participants were enrolled while 7535 older adults were identified from 21 older studies. The results depicted that the mean value of

FRT was 27.5 centimeters with standard deviation of 7.2 centimeters in the new study while the mean value of already published studies was found to be 27.2 centimeters with a standard error of 0.9 centimeters.[50]

Recent study has evaluated the reference norms of FRT along with Lateral Reach test (LRT) and Oblique directional Reach test (ODRT) among children with age group 6-15 years. 300 children were recruited from Kingdom of Saudi Arabia and all the tests were demonstrated among them. The procedure of FRT was same with 90 degree flexed shoulder standing perpendicular to the wall, marking the initial point of 3$^{rd}$ metacarpal. The child was asked to lean forward as much as possible without losing balance. Then the final position was marked and the distance between 2 positions was measured. The lateral reach test was performed by asking the child to stand barefoot facing away from the wall such that his acromian process was leveled at the reference point. Then the child was asked to lean sideways as much as possible and the distance between the initial and an end point of 3rd metacarpal was noted. Then for Oblique direction reach test, a cardboard which is movable has been placed in antero-posterior direction at an angle of 45 degrees. The children were asked to elevate the shoulder at 90 degrees between flexion and abduction of shoulder in scapular plane. Their positions were also marked and the distance between them was identified. The mean and standard deviation of three trials were obtained for each test. It was found that the mean values of FRT, LRT and ODRT were 20.2 (3.1) centimeters, 14.9 (3.3) centimeters and 17.9 (4.0) centimeters respectively among the age of 6 years. These values have found to be increased with age with mean and standard deviation of 33.1 (6.3) centimeters, 25.5 (6.5) centimeters and 28.7 (7.0) centimeters for FRT, LRT and ODRT respectively for 15 years old children.[51]

### 2.7.8 NRV for Clinical Test for Sensory Interaction on balance OR Sensory Organization Test

Clinical Test for Sensory Interaction on Balance (CTSIB) is a clinical measure which has been developed from Sensory Organization Test (SOT) to find the role of sensory system in the maintenance of posture and balance. 6 sub-tests were performed on either firm surface or foam surface with 3 conditions i.e. eyes open, eyes closed and with dome to obstruct the vision. These sub-tests evaluated all the components of balance which are required to maintain it viz. somatosensory system, vestibular system and visual inputs. Subjects were asked to maintain balance in all 6 sub-tests at least for 30 seconds. The score of 3 trials has been recorded and the mean of the trials was calculated. The modified version of CTSIB can also be used with 4 sub-tests having removal of visual conflict dome while standing on firm and foam surface. The normative reference values for mCTSIB have been evaluated among 99 children of age group 9-10 years old. The subjects performed the test and their static stability has been measured by the relative absence of sway. The results of the study showed that composite mean for the sway velocity was 0.712 degrees per second with standard deviation 0.181 degrees per second.[52]

Another study also evaluated the reference values of SOT in children with age 8-12 years. 165 healthy children were recruited for the study and all the 6 sub-tests were performed. It was found that in younger children, balance was maintained for longer duration in SOT 1 which was standing on firm surface with eyes open in comparison to SOT 6 where the children were asked to stand in foam surface with their vision was constantly changing as the surface was also moving. The conditions and scores were better in older children. Regression analysis showed that age is the factor which has a significant effect on all sub-tests of SOT while weight and height affects SOT 2 and SOT 5 respectively.[53]

A list of normative reference values for balance and coordination outcome measures has been extracted from the above literature which has been presented in **Table 2.1.**

**Table 2.1:** Normative reference values for balance and coordination measures

| **Author/ Year** | **Sample (n), age in years** | **Outcome measures** | **Normative Reference values [Mean {S.D.}]** |
|---|---|---|---|
| Costa et al. 2020 | 378, up to the age of 5 years | M-ABC-2 | In UK – 68.4 (66.9-69.8)<br>In Dutch/Flemish - 67.0 (65.6–68.4)<br>In French - 69.4 (67.9–70.8)<br>In Italian - 79.9 (78.3–81.4) |
| Hauser et al. 2020 | 192, (60 - 80) | TUGT, OLS, FRT, TS, CS-5 | 60-69 years = TUGT – 5.3 seconds, OLS – 30.0 seconds, CS-5 – 7.5 seconds, FRT – 37.4 cm, TS – 10.0 seconds<br>70.79 years = TUGT – 5.6 seconds, OLS – 30.0 seconds, CS-5 – 7.4 seconds, FRT – 35.7 cm, TS – 10.0 seconds |
| Libardoni et al. 2018 | 165, (8-12) | CTSIB | 8 years = SOT 1 – 89 (0.8) seconds,<br>SOT 2 – 84.3 (1.0) seconds,<br>SOT 3 – 75.6 (2.8) seconds,<br>SOT 4 – 76 (1.8) seconds,<br>SOT 5 – 42.5 (1.8) seconds<br>SOT 6 – 37.7 (3.0) seconds<br>9 years = SOT 1 – 90.8 (0.5) seconds,<br>SOT 2 – 87.3 (1.6) seconds,<br>SOT 3 – 81.9 (4.2) seconds, |

| | | | |
|---|---|---|---|
| | | | SOT 4 – 83.4 (3.0) seconds,<br>SOT 5 – 48.2 (1.6) seconds<br>SOT 6 – 46.7 (0.9) seconds<br>10 years= SOT 1 – 91.3 (0.7) seconds,<br>SOT 2 – 88.1 (1.2) seconds,<br>SOT 3 – 86.7 (2.2) seconds,<br>SOT 4 – 85.8 (2.2) seconds,<br>SOT 5 – 61.4 (2.1) seconds<br>SOT 6 – 53.9 (2.4) seconds<br>11 years= SOT 1 – 92.4 (0.7) seconds,<br>SOT 2 – 88.0 (0.7) seconds,<br>SOT 3 – 87.9 (2.5) seconds,<br>SOT 4 – 88.0 (2.7) seconds,<br>SOT 5 – 61.2 (2.2) seconds<br>SOT 6 – 61.1 (2.7) seconds<br>12 years= SOT 1 – 93.9 (0.5) seconds,<br>SOT 2 – 89.5 (0.5) seconds,<br>SOT 3 – 87.3 (3.0) seconds,<br>SOT 4 – 85.4 (2.8) seconds,<br>SOT 5 – 76.8 (2.0) seconds<br>SOT 6 – 63.0 (1.5) seconds |
| Dhanani et al. 2014 | 250, (6-17) | Unipedal stance | Unipedal stance = 6-10 years- 1.2 – 1.3 seconds<br>11-15 years- 1.9-2.0 seconds |

| | | | |
|---|---|---|---|
| | | Tandem stance | More than 15 years- 2.7 seconds<br>Tandem Stance = 6-10 years- 1.3 – 1.5 seconds<br>11-15 years- 2.2-2.6 seconds<br>More than 15 years- 2.9-3.5 seconds |
| Pinheiro et al. 2014 | 320, (20- >80) | LEMOCOT | 20-29 years = 48.8 (7.0) seconds<br>30-39 years = 48.8 (8.4) seconds<br>40-49 years = 44.9 (7.8) seconds<br>50-59 years = 40.2 (8.1) seconds<br>60-69 years = 37.1 (9.0) seconds<br>70-79 years = 31.1 (8.3) seconds<br>More than 80 years = 26.7 (8.0) seconds |
| Lanzino et al. 2012 | 69, (60 - >80) | Finger to Nose test<br>Pronation-supination test<br>Mass Grasp test<br>Finger Opposition<br>Heel to Shin test | Finger to Nose Test –<br>60-69 years= 3.6 (1.0) seconds<br>70-79 years= 3.9 (1.0) seconds<br>More than 80 years= 4.6 (1.1) seconds<br>Pronation-Supination test –<br>60-69 years= 2.9 (0.6) seconds<br>70-79 years= 3.0 (0.6) seconds<br>More than 80 years= 3.4 (0.6) seconds<br>Mass Grasp Test –<br>60-69 years= 2.4 (0.8) seconds<br>70-79 years= 2.6 (0.8) seconds<br>More than 80 years= 3.0 (0.8) seconds |

| | | | |
|---|---|---|---|
| | | | Finger Opposition test –<br>60-69 years= 6.5 (1.9) seconds<br>70-79 years= 7.2 (1.9) seconds<br>More than 80 years= 8.2 (1.9) seconds<br>Heel to Shin test –<br>60-69 years= 4.1 (1.1) seconds<br>70-79 years= 4.2 (1.1) seconds<br>More than 80 years= 4.6 (1.1) seconds |
| Geldhof et al. 2006 | 20, (9-10) | CTSIB | 0.712 (0.181) degrees per seconds |
| Steffan et al. 2005 | 96, (61-89) | MDRT, BBS, Sharpened Romberg, Activities-specific Balance Confidence test, Physical Performance Test | MDRT (Forward) = 29 (7) cm<br>MDRT (Backward) = 19 (8) cm<br>MDRT (Left) = 17 (5) cm<br>MDRT (Right) = 17 (5) cm<br>BBS = 53 (4)<br>SRT (eyes open) = 49 (21) seconds<br>SRT (eyes closed) = 29 (24) seconds<br>ABC = 91 (11) percent<br>PPT-7 = 22 (2)<br>PPT-9 = 30 (3) |
| Steffan et al. 2002 | 83, (50-90) | 6MWT, TUGT, BBS, Gait Speed | 6MWT =<br>60-69 years – 555 (92) meters<br>70-79 years – 499 (80) meters |

| | | | |
|---|---|---|---|
| | | | 80-89 years – 404.5 (79) meters<br>TUGT =<br>60-69 years – 55 (1.5)<br>70-79 years – 53.5 (3.5)<br>80-89 years – 51.5 (2.5)<br>BBS =<br>60-69 years – 8 (2) seconds<br>70-79 years – 9 (2.5) seconds<br>80-89 years – 10.5 (2) seconds<br>Gait Speeds =<br>60-69 years – 1.5 (0.24) meters/seconds<br>70-79 years – 1.3 (0.2) meters/seconds<br>80-89 years – 1.2 (0.2) meters/seconds |
| Kahraman BO et al. 2019 | 262, (6-12) | 6MWT | 6 years = 443 (65) meters<br>7 years = 488 (52) meters<br>8 years = 545 (58) meters<br>9 years = 556 (52) meters<br>10 years = 605 (60) meters<br>11 years = 682 (114) meters<br>12 years = 720 (109) meters |
| Casanova C et al. 2011 | 444, (40-80) | 6MWT | 40-49 years = 611 (85) meters<br>50-59 years = 588 (91) meters<br>60-69 years = 559 (80) meters |

| | | | |
|---|---|---|---|
| | | | 70-80 years = 514 (71) meters |
| Chetta A et al. 2006 | 6MWT | 102, (20-50) | Females (Mean age = 33±9 years) = 593 (57) meters<br>Males (Mean age = 36±8 years) = 638 (44) meters |
| Goemans N et al. 2013 | 6MWT | 442, (5-12) | 5 years = 478 (44) meters<br>6 years = 516 (62) meters<br>7 years = 559 (65) meters<br>8 years = 604 (72) meters<br>9 years = 596 (69) meters<br>10 years = 633 (70) meters<br>11 years = 626 (83) meters<br>12 years = 650 (77) meters |

## Chapter 3: Methodology

**3.1 Study design –** A cross-sectional study

**3.2 Study location –** Schools and community

**3.3 Study setting –** Recognized middle schools and community based setting

**3.4 Study Participants –** Typically developing children between age group 8-17 years

**3.5 Sampling –** Stratified random sampling

**3.6 Sample size –** Estimated sample size through pilot testing found to be n=1080 (males: 540, females: 540).

**3.7 Study Duration –** The duration of the study will be from August 2021 to July 2023

**3.8 Selection criteria –**

**3.8.1 Inclusion criteria**

**3.8.1.1** Typically developing school-going children with age group between 8 and 17 years

**3.8.1.2** Both male and female

**3.8.1.3** Able to walk independently

**3.8.1.4** Able to follow verbal commands

**3.8.2 Exclusion criteria**

**3.8.2.1** Any fracture of lower limb in last 6 months

**3.8.2.2** Any congenital anomaly affecting lower limb

**3.8.2.3** Any developmental disorder

**3.8.2.4** Any open wounds

**3.8.2.5** Those who are using any kind of assistive devices

**3.8.2.6** Any condition that affect the health status of the participants during the study

**3.9 Outcome Measures –**

The child will be asked to walk on a 10 meters walkway and the time taken will be noted during –

**3.9.1** Sideways walking

**3.9.2** Tandem walking

**3.9.3** Cross-stepping

**3.9.4** Heel walking

**3.9.5** Toe walking

### 3.10 Ethical Clearance Statement –

Research Advisory Committee of the institute has approved the protocol of the study on August 10th 2021. Ethical approval has been obtained from Institutional Ethical Committee, Maharishi Markandeshwar (Deemed to be University) with Protocol Id: MMDU/IEC/2153. The trial has been registered on ClinicalTrials.gov, resource provided by U.S. National Library of Medicine with registration Id: NCT05159297 and secondary Id has been obtained from WHO registry with Universal Trial Number: U1111-1269-9876. Guidelines of Declaration of Helsinki (2013) and National Ethical guidelines for the Biomedical and Health Research involving Human participants given by Indian Council of Medical Research (2017) will be followed for the study.

### 3.11 Procedure –

The participants who meet the selection criteria will be recruited for the study. As no risk is involved in the study, child's willingness to participate will be required for the data collection[54,55] although permission from the Principal of the respective school will be obtained and written and signed assent will be obtained from each child. The demographic details like age, gender, and height (will be measure through stadiometer), weight (through weighing machine), BMI, limb length and hip circumference (through measuring tape) of the recruited participants will be measured.

First of all, a pilot study has been conducted on a preliminary basis to find the feasibility, accessibility of the participants, limitations in the study and finally to improve the research prior to full-scale study. Children will be asked to wear comfortable clothing with usual footwear. They will be asked to perform all the equilibrium coordination tests one by one following a demonstration of each test but the order of each test will be randomized. Randomization will be done by chit method. If any child would have refractive errors, then he/she will have to wear corrective eye glasses. Six readings of each test will be obtained where three readings will be noted wearing footwear and three readings will be recorded without footwear. Then the average of three readings with footwear and without footwear will be calculated which will be considered as the reference norms for that respective outcome measure in both conditions.

**3.11.1** Sideways walking: Child will be instructed to walk sideways on a 10 meter colored tape pasted on the ground with his feet rested on the starting point. Both hands will be placed on the bilateral iliac crests. When the examiner signals to start by saying, "walk sideways at your comfortable speed up to the mark and GET SET GO". Child will start walking with his governing leg abducted followed by the adduction of the subordinate leg by touching the medial sides of feet together. The time taken will be recorded.

**3.11.2** Tandem walking: Both hands will be placed over the anterior superior iliac spine. The instruction will be given to the child, "Walk with your comfortable speed up to the mark and GET SET GO". The child will be asked to make a contact of heel of one foot with the toes of other foot and then walk along a straight line. Then

place the rear foot ahead of the front foot keeping the same contact of heel of rear foot (now front foot) to toes of front foot (now rear foot)

**3.11.3** Cross-stepping: The child will be asked to stand with feet together and arms hang by the side of the body. Instructions will be given to the child, “Walk at your comfortable speed and GET SET GO”. Then the child will be asked to lift the dominant leg to cross the front of the non-dominant leg with whole body weight supported on non-dominant leg with arms swinging outside. Next the non-dominant leg will be brought back to meet the dominant leg and the process will be repeated with the other leg.

**3.11.4** Heel walking – Both hands will be placed over the anterior superior iliac spine. The child will be instructed to walk at the comfortable speed up to the mark and start at the words, GET SET GO. Ask the child to walk on heels with forefoot lifted from the ground and toes pointed upwards. The participant will be asked to lift the left foot first and place it ahead of right foot with arms swinging by the side of the body and vice-versa

**3.11.5** Toe walking: Both hands will be placed over the anterior superior iliac spine. The child will be instructed to walk at the comfortable speed up to the mark and start at the words, GET SET GO. Ask the child to walk on toes with heel and hind foot raised from the ground. The child will place the toes of left foot first by lifting the

heel and hind foot of the same foot and arms will be hanging by the side of the body. Next place the toes of right foot with raised heel and hind foot of the same.

A mobile-based application stop-watch with Android version 10 QKQ1.190910.002 will be used to record the time for all observations as the child will began to move. All the measurements will be taken during physical activity class/sports period/games period on even or leveled surface as per the scheduled time-table of the particular class.

## Chapter 4: Data Analysis

Statistical Package for the Social Sciences (SPSS) software (IBM) version 20, SPSS Inc. Chicago II USA will be used to analyze the data. Level of significance will be set < 0.05. The normality of the data will be tested through Kolmogorov Smirnov Test. The descriptive statistics will be demonstrated to establish the normative reference values. If the data will found to be normally distributed, then descriptive statistics will be expressed in mean and standard deviations. If the data will not be normally distributed, then descriptive statistics will be expressed in geometric mean and 95% confidence interval. All the anthropometric measurements like age, gender, height, weight, BMI, limb length and waist-hip circumference will be evaluated.

Statistical analysis of the pilot study has been done by estimating the normality of the data using Shapiro Wilk test. The demographic characteristics found to be normally distributed. Hence values have been expressed as mean, standard deviation and standard error mean. Geometric mean, 95% confidence interval and range were used as the outcome measures were not found to be normally distributed.

## Chapter 5: Results

**Table 1: Normality of the demographic and baseline characteristics**

| **Demographic characteristics** | **Mean ± S.D.** | **p-value** |
|---|---|---|
| Age (in years) | 10.85 ± 2.41 | 0.175* |
| Weight (in Kg) | 33.15 ± 10.55 | 0.133* |
| Height (in centimeters) | 138.57 ± 11.73 | 0.330* |
| BMI (in $Kg/m^2$) | 16.79 ± 2.89 | 0.045 |
| Limb Length (in centimeters) | 72.21 ± 7.91 | 0.808* |
| Waist-Hip circumference (in centimeters) | 68.92 ± 7.92 | 0.588* |

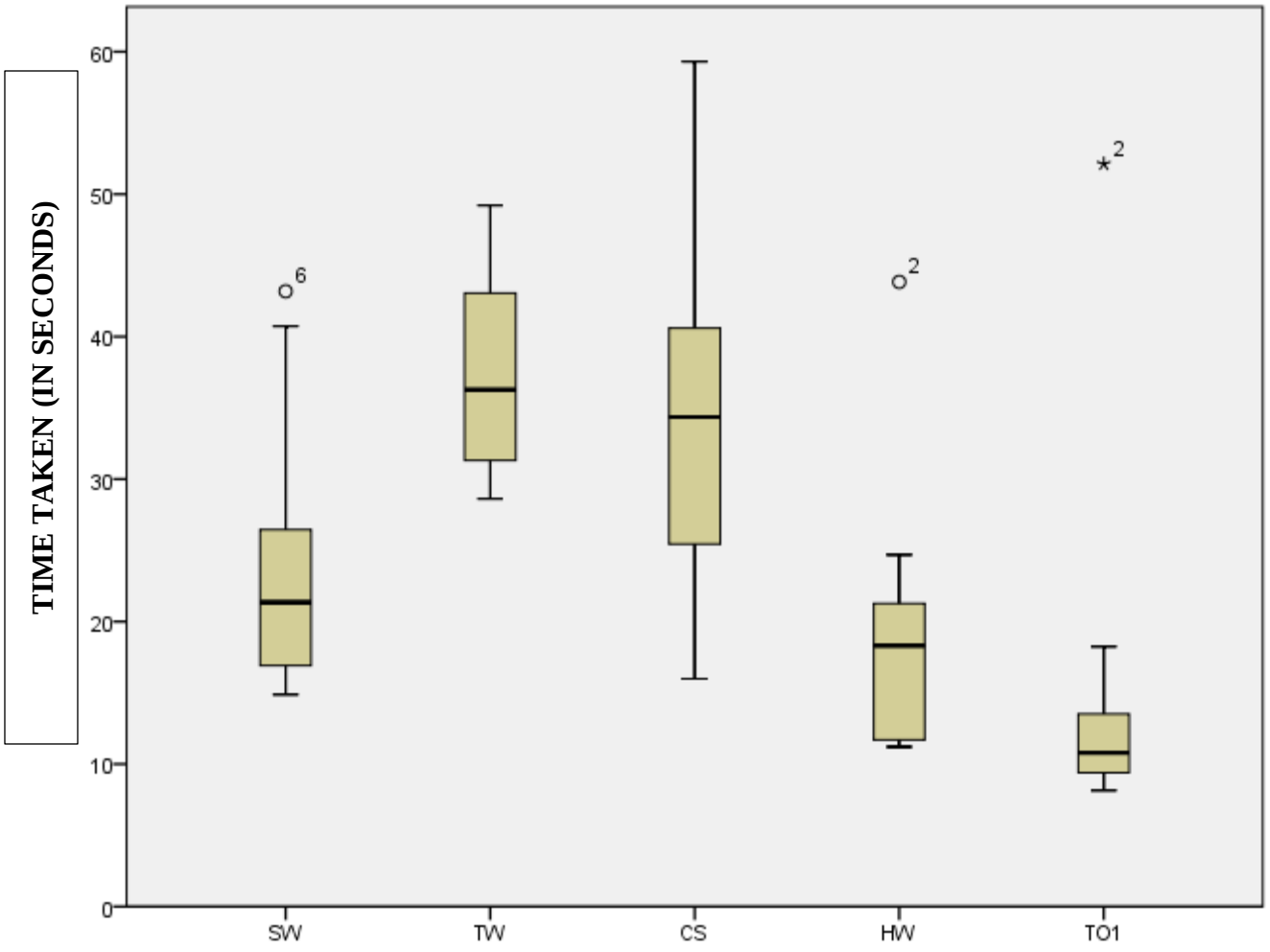
**Abbreviations:** S.D. = Standard Deviation; Kg = Kilograms; p-value = Level of significance

**Table 2: Normative Reference values of sideways walking, tandem walking, cross-stepping, heel walking and toe walking among children (n=14) recruited for the pilot study**

| **Outcome measures** | **Mean (seconds)** | **Standard deviation (seconds)** | **Standard Error Mean (seconds)** | **Geometric Mean (seconds)** | **95% Confidence Interval (seconds)** | **Range (seconds)** |
|---|---|---|---|---|---|---|
| Sideways walking | 23.72 | 8.83 | 2.36 | 22.45 | 18.63-28.83 | 14.88-43.18 |
| Tandem walking | 37.68 | 6.68 | 1.79 | 37.14 | 33.82-41.54 | 28.63-49.22 |
| Cross-stepping | 33.85 | 11.32 | 3.03 | 32.02 | 27.31-40.39 | 15.98-59.30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Heel Walking | 18.55 | 8.82 | 2.36 | 17.05 | 13.46-23.64 | 11.22-43.84 |
| Toe walking | 14.49 | 11.16 | 2.98 | 12.61 | 8.04-20.93 | 8.16-52.12 |

All the measures have been represented in seconds. Tandem walking and Cross-stepping follow the normal distribution; therefore, descriptive statistics have been explained as Mean and Standard Deviation with Standard Error Mean. But Sideways walking, Heel walking and Toe walking are not following normal distribution, hence their geometric mean with 95% confidence interval and range has been calculated.




**Abbreviations: SW= Sideways walking; TW= Tandem walking; CS= Cross-stepping; HW= Heel walking; TO=Toe walking**

**Figure 1: Box and Whisker plot displaying the normative reference values for equilibrium coordination tests**

**The figure showed that time taken for Tandem walking is much more than that of other equilibrium measures.**

- **Calculation of sample size –** Sample size has been calculated using the formula –

N= $((Z\alpha.\sigma)/d)^2$ where, n= required sample size; Zα = significance level (1.96); σ = Standard deviation; d = Standard Error of Mean

1. **Sideways walking**

   N= $((1.96*8.83)/2.36)^2 = 53.73 = 54$

2. **Tandem Walking**

   N= $((1.96*6.68)/1.79)^2 = 53.44 = 54$

3. **Cross-stepping**

   N= $((1.96*11.32)/3.03)^2 = 53.58 = 54$

4. **Heel walking**

   N= $((1.96*8.82)/2.36)^2 = 53.58 = 54$

5. **Toe walking**

   N= $((1.96*11.16)/2.98)^2 = 53.88 = 54$

Thus, a sample of 54 children will be recruited for each age group i.e. 8, 9, 10, 11, 12, 13, 14, 15, 16 & 17 years. Hence, a total sample of 540 (54*10) will be the estimated sample size. This sample will be taken separately for males and females. Thus, a total sample of 1080 will be recruited for the final study.

## Chapter 5: Discussion

The normative reference values will help to identify any abnormality in the equilibrium coordination tests among children with age group 8-17 years. As the data of each age group will be established, it will facilitate to compare the age related changes among children. The study

within the specified age group will be conducted as the executive attention and cognitive function required to control posture and maintain balance are substantially developed after the age of 8 years. Thereby, it is anticipated that these values will also help to identify any attention and cognitive dysfunction among this age group.

Further in secondary analysis, different values for males and females will be accounted and thus, separate norms will be established for both sexes which will be helpful in determining any variation due to gender disproportions. The relationship of body mass index with outcome measures for each age group can also be interpreted which can further be correlated with the coordination and cognition of the individual.

The anticipated limitations of the study could be that measures to standardize the level of motivation among children could not be used. If the child will not be motivated, then he/she will not walk with the required speed.

The study will be done as a multi-center study and not limited to a particular geographical area, so there will be wide variety of children who can be the potential participants with different demographic characteristics. Also the tests are very simple to understand and administer, thus the children will not feel cumbersome to perform. This may proves as a prospective strength of the study.

Future recommendations can be figured on with the reliability and validity of the outcome measures used in the study.

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**ANNEXURE 1**

# INSTITUTIONAL ETHICAL COMMITTEE

**MAHARISHI MARKANDESHWAR INSTITUTE OF MEDICAL SCIENCES & RESEARCH MULLANA, AMBALA**

**Communication of Decision of the Ethics Committee (IEC)**

**Project No: IEC-** 2153

| |
|---|
| **Project Title**: Normative Reference values for sideways walking, tandem walking, cross-stepping, heel walking and toe walking among children |
| Name of Student/Scholar: Nidhi Sharma |
| Name of Institution: MMIPR, MULLANA (AMBALA) |
| ☑ New review ☐ Revised review ☐ Expedited review |
| Date of review (D/M/Y): 13-10-2021<br>Date of previous review, if revised application: ---------- |
| Decision of the Ethics Committee:<br>☑ Recommended ☐ Recommended with suggestions<br>☐ Revision ☐ Rejected |
| Remarks: Approved |
| Recommended for a period of : 1 year |

**Please note ***

- **Inform EC immediately in case of any adverse events and serious adverse events.**
- **Inform EC in case of any change of study procedure, site and investigator**
- **This permission is only for period mentioned above. Annual report to be submitted to EC.**
- **Members of EC have right to monitor the trial with prior intimation.**

Signature of Member Secretary
Ethics Committee
MMIMSR

Member Secretary
Institutional Ethical Committee
M.M. Institute of Medical Sciences
& Research, Mullana (Ambala)

**ANNEXURE 2**

**ClinicalTrials.gov Protocol Registration and Results System (PRS) Receipt**
Release Date: February 8, 2022

**ClinicalTrials.gov ID: NCT05159297**

## Study Identification

Unique Protocol ID: MMDU/IEC/2153

Brief Title: Normative Reference Values of Equilibrium Coordination Test Among Children

Official Title: Normative Reference Values of Sideways Walking, Tandem Walking, Cross-stepping, Heel Walking and Toe Walking Among Children

Secondary IDs: U1111-1269-9876 [Universal Trial Number (WHO)]

## Study Status

Record Verification: February 2022

Overall Status: Recruiting

Study Start: November 2, 2021 [Actual]

Primary Completion: October 2022 [Anticipated]

Study Completion: August 2023 [Anticipated]

## Sponsor/Collaborators

Sponsor: Asir John Samuel

Responsible Party: Sponsor-Investigator
Investigator: Asir John Samuel [asamel]
Official Title: Associate Professor
Affiliation: Maharishi Markendeswar University (Deemed to be University)

Collaborators: Maharishi Markandeshwar International School, Mullana

## Oversight

U.S. FDA-regulated Drug: No

U.S. FDA-regulated Device: No

U.S. FDA IND/IDE: No

Human Subjects Review: Board Status: Approved
Approval Number: MMDU/IEC/2153
Board Name: Institutional Ethics Committee
Board Affiliation: Maharishi Markandeshwar (Deemed to be University)
Phone: 8059930001
Email: msecmmu@mmumullana.org
Address:

Member Secretary, Institutional Ethics Committee, Maharishi Markandeshwar (Deemed to be University)

Data Monitoring: Yes

FDA Regulated Intervention: No

## Study Description

Brief Summary: A cross-sectional study will be conducted recruiting children of age group 8-15 years. Pilot study has been conducted for the determination of the sample size. The calculated sample size has come out to be, n=378 which can be taken for males and females separately. Stratified random sampling will be done according to age. Child will be asked to perform all tests one by one and the time taken (in seconds) will be noted required to perform the tests. The mean of three readings will be obtained using a mobile-based stop watch.

Detailed Description: 756 children will be recruited of age group 8-15 years. Five equilibrium coordination tests i.e. Sideways walking, tandem walking, cross-stepping, heel walking and toe walking will be performed by each child and three readings will be recorded. Mean of three readings will be considered as normative reference value of each test respectively.

## Conditions

Conditions: Coordination Disorder, Developmental

Keywords: children
coordination
normal range
postural balance
walking

## Study Design

Study Type: Observational

Observational Study Model: Case-Only

Time Perspective: Cross-Sectional

Biospecimen Retention: None Retained

Biospecimen Description:

Enrollment: 378 [Anticipated]

Number of Groups/Cohorts: 1

## Groups and Interventions

Intervention Details:
Reference values
Normative reference values of coordination tests will be obtained

## Outcome Measures

Primary Outcome Measure:

1. Sideways walking
   This test will be used to find the normative values of sideways walking

[Time Frame: Immediately after the sideways walking]

2. Tandem walking
   This test will be used to find the normative values of tandem walking

   [Time Frame: Immediately after the Tandem walking]
3. Cross stepping
   This test will be used to find the normative values of cross stepping

   [Time Frame: Immediately after the Cross stepping]
4. Heel Walking
   This test will be used to find the normative values of heel walking

   [Time Frame: Immediately after the Heel Walking]
5. Toe walking
   This test will be used to find the normative values of toe walking

   [Time Frame: Immediately after the Toe walking]

## Eligibility

Study Population: Normal healthy children of age group between 8 and 15 years will be recruited

Sampling Method: Probability Sample

Minimum Age: 8 Years

Maximum Age: 15 Years

Sex: All

Gender Based: No

Accepts Healthy Volunteers: Yes

Criteria: Inclusion Criteria:

- Typically developing school-going children with age group between 8 and 15 years
- Both male and female
- Able to walk independently
- Able to follow verbal commands

Exclusion Criteria:

- Any fracture of lower limb in last 6 months
- Any congenital anomaly affecting lower limb
- Any developmental disorder
- Any open wounds
- Those who are using any kind of assistive devices
- Any condition that affect the health status of the participants during the study

## Contacts/Locations

Central Contact Person: Nidhi Sharma, PhD Scholar
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Study Officials: Nidhi Sharma, PhD Scholar
Study Principal Investigator
Maharishi Markendeshwar University (Deemed to be University)

Locations: **India**
Maharishi Markandeshwar International School
[Recruiting]
Ambāla, Haryana, India, 133207
Contact: Radhika Aggarwal, MA, B.Ed.

## IPDSharing

Plan to Share IPD: No

## References


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Links:

Available IPD/Information:

ClinicalTrials.gov PRS
Protocol Registration and Results System

ID: MMDU/IEC/2153 Normative Reference Values of Equilibrium Coordination Test Among Children NCT05159297

**Protocol Registration Preview**

This is a rough approximation of how the Protocol Registration will appear on the ClinicalTrials.gov public web site.

# Normative Reference Values of Equilibrium Coordination Test Among Children

⚠ The safety and scientific validity of this study is the responsibility of the study sponsor and investigators. Listing a study does not mean it has been evaluated by the U.S. Federal Government. Read our disclaimer for details.

ClinicalTrials.gov Identifier: NCT05159297

Recruitment Status: Recruiting
First Posted: *
Last Update Posted: *

* Date not available in PRS

**Sponsor:**

Asir John Samuel

**Collaborators:**

Maharishi Markandeshwar International School, Mullana

**Information provided by (Responsible Party):**

Asir John Samuel, Maharishi Markendeswar University (Deemed to be University)

## Study Description

Brief Summary:

A cross-sectional study will be conducted recruiting children of age group 8-15 years. Pilot study has been conducted for the determination of the sample size. The calculated sample size has come out to be, n=378 which can be taken for males and females separately. Stratified random sampling will be done according to age. Child will be asked to perform all tests one by one and the time taken (in seconds) will be noted required to perform the tests. The mean of three readings will be obtained using a mobile-based stop watch.

| Condition or disease | Intervention/treatment |
|---|---|
| Coordination Disorder, Developmental | Reference values |

Detailed Description:

756 children will be recruited of age group 8-15 years. Five equilibrium coordination tests i.e. Sideways walking, tandem walking, cross-stepping, heel walking and toe walking will be performed by each child and three readings will be recorded. Mean of three readings will be considered as normative reference value of each test respectively.

## Study Design

Study Type: Observational

| | |
|---|---|
| Estimated Enrollment: | 378 participants |
| Observational Model: | Case-Only |
| Time Perspective: | Cross-Sectional |
| Official Title: | Normative Reference Values of Sideways Walking, Tandem Walking, Cross-stepping, Heel Walking and Toe Walking Among Children |
| Actual Study Start Date: | November 2, 2021 |
| Estimated Primary Completion Date: | October 2022 |
| Estimated Study Completion Date: | August 2023 |

## Groups/Cohorts

Number of groups: 1

Intervention Details:

Reference values

Normative reference values of coordination tests will be obtained

## Outcome Measures

Primary Outcome Measure:

1. Sideways walking [Time Frame: Immediately after the sideways walking]

   This test will be used to find the normative values of sideways walking

2. Tandem walking [Time Frame: Immediately after the Tandem walking]

   This test will be used to find the normative values of tandem walking

3. Cross stepping [Time Frame: Immediately after the Cross stepping]

   This test will be used to find the normative values of cross stepping

4. Heel Walking [Time Frame: Immediately after the Heel Walking]

This test will be used to find the normative values of heel walking

5. Toe walking [Time Frame: Immediately after the Toe walking]

This test will be used to find the normative values of toe walking

## Eligibility Criteria

| | |
|---|---|
| Ages Eligible for Study: | 8 Years to 15 Years |
| Sexes Eligible for Study: | All |
| Gender Based: | No |
| Accepts Healthy Volunteers: | Yes |
| Sampling Method: | Probability Sample |

**Study Population**

Normal healthy children of age group between 8 and 15 years will be recruited

**Criteria**

Inclusion Criteria:

- Typically developing school-going children with age group between 8 and 15 years
- Both male and female
- Able to walk independently
- Able to follow verbal commands

Exclusion Criteria:

- Any fracture of lower limb in last 6 months
- Any congenital anomaly affecting lower limb

- Any developmental disorder
- Any open wounds
- Those who are using any kind of assistive devices
- Any condition that affect the health status of the participants during the study

## Contacts and Locations

### Contacts


| | | |
|---|---|---|
| Nidhi Sharma, PhD Scholar | 9760835605 | sharmanidhiphysio@gmail.com |
| Asir J Samuel, PhD | 8059930222 | asirjohnsamuel@mmumullana.org |


### Locations

**India**

Maharishi Markandeshwar International School **Recruiting**
Ambāla, Haryana, India, 133207
Contact: Radhika Aggarwal, MA, B.Ed.

### Investigators

| | | |
|---|---|---|
| Principal Investigator: | Nidhi Sharma, PhD Scholar | Maharishi Markendeshwar University (Deemed to be University) |

## More Information

Publications:


Aylar MF, Dionisio VC, Jafarnezhadgero A, Parikhani AZ. Body coordination during sit-to-stand in blind and sighted female children. J Biomech. 2020 May 7;104:109708. doi: 10.1016/j.jbiomech.2020.109708. Epub 2020 Feb 28.

Riquelme I, Arnould C, Hatem SM, Bleyenheuft Y. The Two-Arm Coordination Test: Maturation of Bimanual Coordination in Typically Developing Children and Deficits in Children with Unilateral Cerebral Palsy. Dev Neurorehabil. 2019 Jul;22(5):312-320. doi: 10.1080/17518423.2018.1498552. Epub 2018 Jul 19.

McKay MJ, Baldwin JN, Ferreira P, Simic M, Vanicek N, Burns J; 1000 Norms Project Consortium. Normative reference values for strength and flexibility of 1,000 children and adults. Neurology. 2017 Jan 3;88(1):36-43. doi: 10.1212/WNL.0000000000003466. Epub 2016 Nov 23.

Bolk J, Farooqi A, Hafström M, Åden U, Serenius F. Developmental Coordination Disorder and Its Association With Developmental Comorbidities at 6.5 Years in Apparently Healthy Children Born Extremely Preterm. JAMA Pediatr. 2018 Aug 1;172(8):765-774. doi: 10.1001/jamapediatrics.2018.1394.

Dunsky A. The Effect of Balance and Coordination Exercises on Quality of Life in Older Adults: A Mini-Review. Front Aging Neurosci. 2019 Nov 15;11:318. doi: 10.3389/fnagi.2019.00318. eCollection 2019.

Lanzino DJ, Rabinstein A, Kinlaw D, Hepburn SB, Ness BM, Olson KJ, Sobie SM, Hollman JH. Coordination tests in persons with acute central nervous system pathology: assessment of interrater reliability and known-group validity. J Neurol Phys Ther. 2012 Sep;36(3):122-30. doi: 10.1097/NPT.0b013e3182641d36.

| | |
|---|---|
| Responsible Party: | Asir John Samuel, Associate Professor, Maharishi Markendeswar University (Deemed to be University) |
| ClinicalTrials.gov Identifier: | NCT05159297 |
| Other Study ID Numbers: | MMDU/IEC/2153<br>U1111-1269-9876 |
| Last Verified: | February 2022 |

Individual Participant Data (IPD) Sharing Statement:

Plan to Share IPD: No

Human Subjects Protection Review Board Status: Approved

Studies a U.S. FDA-regulated Drug Product: No

Studies a U.S. FDA-regulated Device Product: No

# ANNEXURE 3

## Universal Trial Number validation

U1111-1269-9876 Validate Clear Help

**This utn number is valid.**

Disclaimer: Trials posted on this search portal are not endorsed by WHO, but are provided as a service to our users. In no event shall the World Health Organization be liable for any damages arising from the use of the information linked to in this section. None of the information obtained through use of the search portal should in any way be used in clinical care without consulting a physician or licensed health professional. WHO is not responsible for the accuracy, completeness and/or use made of the content displayed for any trial record.

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## ANNEXURE 4

## Data Collection Form

**Reference number –**

**Name –**

**Age (years) –**

**Gender –**

**Height (cm) –**

**Weight (kg) –**

**BMI (kg/m$^2$) –**

**Lower Limb Length (cm) – Right side** **Left side**

**Hip circumference (cm) –**

**Waist circumference (cm) –**

**Outcome Measures –**

| **Outcome Measures** | **Time taken (in seconds)** | | | | | |
|---|---|---|---|---|---|---|
| | **With Footwear** | | | **Without Footwear** | | |
| | **Reading 1** | **Reading 2** | **Reading 3** | **Reading 1** | **Reading 2** | **Reading 3** |
| **Sideways walking** | | | | | | |
| **Tandem walking** | | | | | | |
| **Cross-stepping** | | | | | | |
| **Heel Walking** | | | | | | |
| **Toe walking** | | | | | | |

## ANNEXURE 5

## Permission letter from School Principal

Date : 03rd September, 2021

To

The Principal
MM International School
Mullana-Ambala

Through

The Principal
MM Institute of Physiotherapy and Rehabilitation
Mullana-Ambala

**Subject- Permission for research work (Data Collection) in MM International School**

Respected Madam,

I, Dr. Nidhi Sharma, (Associate Professor in MMIPR) am pursuing my Doctorate of Philosophy (Roll No. 1820743) on the topic, "Normative Reference values of sideways walking, tandem walking, cross-stepping, heel walking and toe walking among children". The required age of the children for the study is 8 to 15 years. So, I request you if you kindly permit me to take data of the children from your reputed school. There is no harm or any risk involved during the study procedure. I will collect the data during their sports lecture/games period/activity period so that their studies will not be affected.

Kindly allow me for the same. I shall be very thankful to you.

Thanks and Regards

Nidhi Sharma
PhD. Scholar
1820743
Contact No. 9760835605

Forwarded to the principal MM International School through the principal, MMIPR.

Dr. A. John Samuel
PhD (Physiotherapy)
& Pediatric Neuro)

(PhD Supervisor)

8/9/2021

Principal
M. M. International School
Mullana (Ambala)

Forwarded to Principal. Kindly do the needful.

3 Sept 2021

MM Institute of Physiotherapy & Rehabilitation

**ANNEXURE 6**

**Plagiarism Report**

URKUND

## Urkund Analysis Result

**Analysed Document:** Synopsis_21.08.2021.docx (D111531726)
**Submitted:** 8/21/2021 9:26:00 AM
**Submitted By:** asirjohnsamuel@mmumullana.org
**Significance:** 1 %

Sources included in the report:

https://ir.library.oregonstate.edu/downloads/zk51vj924

Instances where selected sources appear:

1